DEVELOPMENT OF TECHNOLOGY TO EXCLUDE FERAL ANIMAL FEED CONSUMPTION FROM CALF CREEP FEEDERS

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DEVELOPMENT OF TECHNOLOGY TO EXCLUDE

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CREEP FEEDERS

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NOMENCLATURE

FMDv	foot and mouth disease virus
RFID	radio frequency identification

CHAPTER I

INTRODUCTION

Creep feeding is a long standing practice in the cattle industry, with the some of the first references in the scientific literature coming as early as 1936. Creep feeding is defined as the supplementing of the diet of grass and milk for unweaned calves with feed not available to the mother (Herd et al., 1998). Creep feeding has always been a valuable tool for producers in many situations, including when forage is limited, when growing larger framed calves, with first calf heifers, and when producing calves to go straight to the feedlot. Unfortunately, in recent years creep feeding has fallen into disuse due to issues with poor feed efficiency and feral animal interference.

It has long been known that animals on creep feed exhibit poor feed efficiency. In a 1987 summary of 31 creep feeding studies, Ritchie found that on average it took 9 lb of creep feed to produce 1 lb of gain in calves. This low feed conversion reduces the economic feasibility of creep feeding. Some of the reported low feed conversion numbers may be due to feral animal feed consumption and wastage, as feral animals including feral swine (*Sus scrofa)* and raccoons (*Procyon lotor)* are known to enter creep feeders and consume feed, sorting the feed and causing wastage in the process.

Feral swine and raccoons have also been seen to completely enter feed troughs, causing contact between feed and feral animal feces, mucal secretions and other bodily fluids, as well as contact between the bottoms of the animals' feet and the feed itself. Feral swine in particular have been shown to spread at least thirty different viral and bacterial diseases (Williams et al., 2001), and 37 different parasites (Forrester, 1991). Many of these diseases can be spread through direct contact, as well as through animal contact with feces and bodily fluids. This presents a significant animal health concern, and by proxy is a concern to public health in humans.

The objective of this experiment is to develop a system to exclude feral animals from entry and feeding a calf creep feeding sites. This will be done in an economical system that is practical to farmers and ranchers in a production setting. This will also be done with portability and reliability in mind. A secondary objective is to create a mobile data monitoring system to be included on the creep feeder for recording data such as attendance statistics and rumen temperature, which may have many future uses and implications.

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CHAPTER II

REVIEW OF LITERATURE

INTRODUCTION

Creep feeding is the supplementing of the diet of grass and milk of unweaned calves with feed that is not available to the mother (Herd et al., 1998). Feeds used during creep feeding generally fall into one of three classes: free choice, energy based creep feeds; limited intake, protein based creep feeds, and forage based creep feeds, also known as creep grazing (Lardy et al., 2007).

The value of creep feeding pastured calves has long been recognized. Bray reported as early as 1934 that calves creep fed for 133 d gained 40 percent more than calves on pasture alone, and calves creep fed for 70 d gained 28.4 percent more than calves on pasture alone. Powell (1936) noted an increased average gain of 27.2 kg in calves provided with supplemental creep feed over the grazing season as compared to grazing calves. He further observed that creep fed calves were more uniform, and in times of high grain prices, received higher premiums at sale due to their increased weight. Powell also noted that mothers of creep fed calves gained more weight over the summer grazing season, bred back more smoothly, and produced a heavier calf crop the subsequent year. Cunningham et al. reported in 1958 that creep feeding of purebred nursing calves increased weaning weights of steers by 37.6 kg and heifers by 19.5 kg. They further demonstrated that supplemental feeding increased ADG of steers by 0.3 kg and heifers by 0.2 kg when creep fed. Reed and others (2006) found that creep feeding with a fiber based creep ration improved organic matter and nitrogen digestibility in nursing calves grazing native range in North Dakota. Other benefits of creep feeding include easing the stress of weaning, and better preparing calves for the feedlot by teaching them to better consume solid feed (Herd et al., 1998).

POTENTIAL PROBLEMS ASSOCIATED WITH CREEP FEEDING

Empirical evidence suggests that several species of wild animals visit creep feeders, including feral swine (*Sus scrofa*) and raccoons (*Procyon lotor*). Of these two, feral swine present the largest danger. In 2000, feral swine were estimated to have a population of at least 4 million animals, causing damage in excess of $800 million annually in the United States (Pimentel et al., 2000). This number has surely increased, because in 2000, feral swine were only known to be present in 30 states (Bergman et al., 2002), but by 2006, they had spread to 44 different states (Hutton et al., 2006). In addition to damage caused by feral swine, there is the danger of the spread of disease, a potentially much more devastating issue. Feral swine and cattle have been shown to have direct contact, even on very large ranches, at congregation points such as water and food sources (Cooper et al., 2010). Direct contact, as defined by Cooper et al., consists of two animals passing within 20 meters of the same area, within 15 minutes of each other. Researchers have also shown that feral swine are a reservoir for at least thirty different viral and bacterial diseases (Williams et al., 2001), and can house 37 different parasites (Forrester, 1991). Of these, several diseases and parasites are of concern to the US cattle industry, and by proxy represent a danger to humans. Feral swine in Florida have been found to have antibodies to *Brucella* bacterium (Van der Leek et al., 1993). Brucellosis outbreaks in cattle have historically been strongly correlated with brucellosis outbreaks in humans, making prevention of interactions between feral swine and cattle a high priority (Wise, 1980). Another potentially devastating disease that feral swine are susceptible to is foot and mouth disease virus (Dudley et al., 2002). In 2001, the United Kingdom had an outbreak of foot and mouth disease that was estimated to have caused final losses greater than US $12 billion (Pearson et al., 2005). Another assessment highlights foot and mouth disease as the most costly disease of livestock in the world (Meyer et al., 2001). Transmission of foot and mouth disease generally occurs through direct contact between animals (Samuel et al., 2001), which has been shown to occur between feral swine and cattle at a very low but significant rate, even on large rangeland areas (Cooper et al., 2010). Foot and mouth disease can be transmitted via contaminated feed, soil and water, or by excrement (Sellers, 1971), which makes the control of feral swine visitation to creep feeding sites extremely important. Paarlberg et al. (2002) suggested that an outbreak of foot and mouth disease in the US could cause losses over $14 billion in farm income.

Another species of interest known to visit creep feeders on a regular basis is the common raccoon, *Procyon lotor*. In 1995, a raccoon-vectored outbreak of *Mycobacterium bovis*, the causative agent behind bovine tuberculosis, resulted in government mandated depopulation of five northern Michigan beef cattle operations (Atwood et al., 2009). In 2007, Lyautey et al. isolated *Listeria monocytogenes* bacteria from raccoon feces in Ontario, Canada, showing another possible source of cattle feed contamination. Some strains of *L. monocytogenes*, that favor conditions at cattle operations, cause severe listeriosis leading to acute death in dairy cattle (Bundrant et al., 2011). Such results demonstrate the potentially dangerous effects of raccoon cross-contamination with *L. monocytogenes.* Raccoons are known to carry rabies, a fatal disease in humans, which also affects a small but significant number of cattle each year, accounting for 0.9% of all reported animal rabies cases in 2009. (Blanton et al, 2009). These issues show the importance of precluding raccoons from interacting with cattle at creep feeding locations.

SOLUTIONS USING TECHNOLOGY

The simplest solution to the issue of feral animal invasion in to creep feeders may be new technology to exclude wild animals, while still allowing calves to feed unhindered. This is a very promising area of future research, and a breakthrough could allow creep feeding to remain a viable option in the face of growing populations of feral swine and other non-intended species. Technological solutions such as this may also allow for more individually targeted creep feeding, based on the particular needs of each calf, which could lead to increased efficiency and a more uniform calf crop. This will most likely be accomplished by using some sort of door mechanism that identifies calves, opening and allowing them to feed, and closing after exit, effectively excluding feral animals from feeding. One of the main hurdles inherent to design ideas such as this, and also the focus of much current technological research, is a method to identify calves at a distance, with accuracy and consistency. Traditionally, many methods, especially ear tags and brands, have been used to visually identify cattle (Wismans, 1999). However, electronic solutions that could be used in a feral animal exclusion system are becoming more applicable and affordable, with many organizations, including the U.S. Department of Agriculture, pushing for nationwide electronic tagging of all livestock (Swedberg, 2008). The main form of electronic identification is the RFID ear tag, meaning radio frequency identification, of which there are two types: passive and active. Passive RFID is the oldest and most widely adapted. Among the first uses of passive RFID technology in the livestock industry was in the form of a collar mounted transmitter, to individually feed cattle for research purposes (Rossing, 1976). This method is still widely used in research, especially dairy cattle lactation trials. Since then, passive RFID has evolved into a wide array of applications, including injectable transmitters, primarily used in companion animals, and ear tag transmitters, the preferred method of the U.S. Department of Agriculture (Eradus, 1999). However, passive RFID technology is generally limited to a range of only a few feet (Browne, 2010), making a different technology, active RFID, much more applicable in pastured cattle operations. Active RFID transmitters contain a small battery, allowing for much greater range, smaller receiver antennae, and data storage possibilities (Browne, 2010). Active RFID transmitters have been incorporated into rumen boluses, which have been shown to be safe for use in the identification of sheep, goats and cattle (Caja, 1999). Future research may be focused at incorporating active RFID transmitters into cattle ear tags, which would provide reusability and greatly increased range. These technologies, when combined with future creep feeder developments, will create a system that allows creep feeding to continue to be sustainable even considering current pressures.

SUMMARY

Creep feeding is a longstanding method of supplementation in pastured calves, with the first references in the literature occurring as early as 1934. However, with the growth and expansion of the feral pig population in the United States, creep feeding has come under increased pressure due to economic losses associated with feed disappearance and disease interactions. Feral swine in particular are known to carry *Brucella* bacterium, the causative agent behind the deadly brucellosis disease, as well as foot and mouth disease virus, the most economically damaging livestock disease worldwide. In addition, the common raccoon can carry several livestock damaging microbes, including *M. bovis*, the causative agent behind bovine tuberculosis, and *L. monocytogenes*, the causative agent behind listeriosis, and rabies, a disease that affects all mammals. Due to these issues, and the enormous danger to the United States cattle industry, it is imperative that feral animal and cattle interactions at creep feeders be minimized through the use of multivaried means, including population control and the development of new technologies.

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CHAPTER III

SENSOR TECHNOLOGY FOR THE IDENTIFICATION OF CALVES AT CREEP FEEDING SITES

ABSTRACT: An experiment was performed to evaluate three different electronic sensor systems for accuracy of identifying calves attending a mobile creep feeder. Additionally, efficacy of sensor placement for active RFID rumen technologies was evaluated. Fifty seven post-weaning calves were stratified by weight and randomly assigned by to three pastures, each containing a single creep feeder outfitted with one of several combinations of electronic sensor technologies. All calves were also administered an active RFID rumen bolus (Strategic Solutions Interational, LLC, Stillwater, OK). Creep feeders 1 and 3 were equipped with three active RFID readers, one on the left side of the feeder, one on the right, and one suspended on a post on the center of the feeder. Creep feeder 2 was equipped with the same configuration of active RFID readers, as well as one directional RFID reader, and one large size passive RFID panel reader (Destron Fearing, St. Paul, MN). Each feeder was also equipped with ultrasonic sensor systems, although due to equipment failures these systems did not produce any results. Active RFID data was collected for 25 d, passive RFID data was collected for 4 d, video cameras recorded the same 4 d, for evaluation of accuracy of active and passive data. This data was analyzed to find accuracy of passive RFID sensor technology, maximum gap in receptions for each active RFID sensor configuration, and also to determine any general improvements to each system. It was determined that the passive RFID system was able to detect 87% of calf entries into the feeder. It was also found that the average of the highest amount of time between active RFID message receptions between all receivers was 0:07:14±0:06:47 (h:mm:ss) during a congregation where calves were physically present at the feeder. Data from this study suggests that active RFID bolus transmitters may be suitable for identification of calf attendance at creep feeding sites.

Key words: Cattle, active RFID, passive RFID, EID, rumen bolus, creep feed

INTRODUCTION

Cattle identification technology has seen many advances as of late, with the introduction of commercial passive and active RFID ear tags and boluses. Much of this technology has been used extensively in other industries, including bar codes and package tracking. Passive RFID has also become standard in many countries as part of the mandatory animal identification program. So far, in the cattle industry these technologies have seen only limited use, mainly in the feedlot and dairy sectors. However, with the cheapening cost of electronic identification technology and rising cost of raising cattle, solutions at all levels of production are becoming economically viable.

Passive RFID systems are the preferred method of identification for many situations, due to their relatively cheap ear tag transmitters, and are generally the only form of RFID identification produced by major tag companies. However, passive RFID systems have many drawbacks, including extremely expensive and large antennae and readers, which have high power consumption. This may make them less than ideal for mobile applications in pasture systems. Active RFID setups have a higher per transmitter cost, but have a much higher read range and require smaller antennae that consume less power. Therefore, active RFID may be much more applicable in pasture or range situations. Ultrasonic motion detection sensors have also been considered and were tested, although they have several distinct disadvantages. Mainly, they cannot separate cows from calves or calves from feral animals. The objective of this experiment was to determine which RFID system is most ideal for attachment to a mobile creep feeder to be used in range settings with many varied applications, including identification, herd health and feed distribution.

MATERIALS AND METHODS

Cattle

Fifty seven post-weaning calves (average BW=299±42.05 kg) were selected in January 2010 from the Oklahoma State University north range herd. Each calf was weighed on January 15, 2010 and administered a uniquely identified, temperature sensing, active RFID rumen bolus (Strategic Solutions International LLC, Stillwater, OK) shown in Figure 3.1. Calves were stratified by weight and randomly allotted into three groups of 19 head, which were each assigned to one of three pastures. During video recorded phases of the study, calves in each field were assigned a number one through nineteen, which was paint branded onto the calves' face for video identification purposes (Figure 3.2). Throughout the study, calves were fed a creep feed diet ad libitum with up to 15% salt added as a feed intake limiter (Table 3.1).

Treatments

Three creep feeders constructed by the 3C Cattle Feeder Company (Mill Creek, OK) were outfitted with sensor setups and one feeder was placed in each of three pastures. See figure 3.3 for a pasture map, and figure 3.4 for a view of the basic creep feeder. Within each pasture, supplemental cow mineral was positioned near the calf creep feeder, supplemental cow feed was provided throughout the pasture using a cake feeder mounted on a pickup truck, and water sources were located on the opposite side of the pasture from calf creep feeders. All feeders were placed with one side outfitted with receiver technology and available for feeding, and the other side placed against a fence and not used for feeding. Pasture 1 consisted of a feeder outfitted with left, center, and right active RFID readers, positioned on the north side of a 72 acre pasture, near the gate. Pasture 2 consisted of a feeder outfitted with left, center, and right active RFID readers, as well as a directional active RFID reader, and a large sized stationary passive RFID reader panel (Destron Fearing, St. Paul, MN) connected to a laptop for data storage. The directional active RFID reader consisted of a standard active RFID reader surrounded by a foil box, with only one side uncovered, allowing messages to be read only directly in front of the feeder. The passive RFID reader panel was attached to the metal creep feed bars, with a piece of plywood placed between the panel and bars in order to prevent interference from the bars. Two of the three entrances to the feeder in pasture 2 were blocked, in order to ensure that calves passed by the passive RFID reader panel (Figure 3.5). The feeder in pasture 2 was positioned on the farthest east side of a 102 acre pasture. Pasture 3 consisted of a feeder similar to pasture 1, with left, center and right active RFID readers, with the feeder also positioned on the east side of a 51 acre pasture. In both pastures 1 and 3, the center active RFID reader was suspended on a post above the creep feeding area while the left and right active RFID readers were mounted on either side of the feeding area itself. See figure 3.7 for a diagram of receiver placement. All three feeders were also equipped with ultrasonic motion detection sensors.

Data Collection

During this experiment, calves were on pasture for 41 d, including a 16 d adaptation period. After the adaptation period, active RFID sensor data was collected for 25 d. This consists of the time each message was received, as well as the unique ID number of the bolus from which it was received, and the number of the receiver that recorded the message. This data was collected by the three receivers positioned on the feeder, and relayed wirelessly to another receiver connected to a laptop, where the data was stored in a database. On treatment 2, passive RFID data was collected for 72 hrs during wk three of the trial. The data collected consists of the animal's unique 15 digit passive RFID number, as well as the time the passive RFID tag passed adjacent to the reader. For the same 72 hrs during the third wk of the trial, video data was collected on each of the feeders using a four camera surveillance system produced by Digital Peripheral Systems, Inc. (Anaheim, California) diagramed in figure 3.6. This video data was viewed and the identification number of each calf as it visited the creep feeder was recorded, along with the time of calf entry into the feeder, and the time of calf exit from the feeder.

Data Analysis

On active RFID equipped treatments one, two and three, video data was first summarized to determine the identification number of each calf as it visited the creep feeder, along with the time of entry into the feeder, the time of exit from the feeder, and the duration of the stay. This data was then summarized to determine the start and end time of feeding congregations at each creep feeder. A congregation was defined as a period of time where calves were continuously present feeding, with a break of no longer than five minutes. Congregation times were determined using the entry and exit times of each individual calf, recorded from analysis of the video data. Based on video data, active RFID reception data for individual calves was selected for the time calves were within the feeder. For each receiver, the active RFID data collected while a calf was present at the feeder was combined for each congregation event and the smallest amount of time between RFID message receptions ("minimum gap") and highest amount of time between RFID message receptions ("maximum gap") during each congregation where calves were physically present at the feeder was determined. This data was then summarized to determine the highest maximum gap seen on each receiver for each d ("Daily max gap"), and the average of the highest gaps from each congregation event on each receiver for each d ("Event max gap"). The daily maximum gap and event maximum gap were analyzed using proc mixed in SAS 9.2 (SAS Institute Incorporated, Cary, NC). The purpose of this analysis was to determine which feeder setup produced the lowest possible gaps in receptions. After analysis, additional analysis was performed on feeder two to determine which receiver location produced the lowest gaps in receptions. The average event maximum gaps were determined for each receiver on each feeder. These averages were then summed and averaged in order to determine one overall number that indicated the lengths of time to allow between receptions before determining that no calves were present at the feeder.

On treatment two, passive RFID data was gathered and evaluated to determine the success rate at detecting the entry of the calf to the feeder, as well as the success rate at detecting the exit of the calf from the feeder. A successful entrance message was defined as detecting a message from the passive RFID tag within one minute of the calf physically entering the feeder. Likewise, a successful exit message was defined as detecting a message from the passive RFID tag within one minute of the calf physically leaving the feeder. The number of successful entrance messages was then averaged with the total number of physical entrances to get the entrance detection success rate. The same was done with exit messages in order to find the exit detection success rate.

Video data was summarized from all three feeders to determine visits to the feeder per calf per d, and length of each visit. These calculations were juxtaposed with data from the active RFID receivers, from which visits per d per calf was estimated by using a gap in reception of signals from a calf of five minutes or longer to delineate a new visit to the feeder. This data was analyzed using a least mean squares setup in proc mixed of SAS 9.2 (SAS Institute Incorporated, Cary, NC). The visual and electronic attendance data was also plotted in a comparison to determine the R^2 value of the correlation.

RESULTS AND DISCUSSION

The ultrasonic motion detection sensors tested in this project failed to detect cattle and were deemed not appropriate for cattle applications due to their poor temperature range and tendency to malfunction in rain and snow. The passive RFID technology on treatment feeder 2 proved to be the most successful at detecting individual entrances and exits from the feeder, with an 87% entrance detection rate and a 77% exit detection rate. In order to ensure that all calves enter past the passive RFID antenna, two of the three creep feeder entrances must be covered (Figure 3.5). This restriction may cause behavioral changes that could lead to reduced feed intake. Alternatively, multiple RFID antennae would have to be installed on each feeder, which would be much less economically practical. Also, although passive RFID ear tags are much less expensive than active RFID transmitters, the initial investment involved in purchasing the passive RFID antenna and controller puts this technology out of reach of most small to medium scale cow calf operators. Finally, passive RFID technology lacks the herd health and detection abilities of active RFID technology, because passive RFID transmitters can only be read eighteen to thirty inches from the antenna.

It was found that the average event maximum gap across each of the three active RFID sensors on each of the three feeders (n=9) was seven minutes and fourteen seconds with a standard deviation of six minutes and forty-seven seconds. This number is heavily biased by the high event maximum gap numbers on the three sensors on treatment feeder one (Table 3.2). For this experiment, feeder mounted transceivers transmitted data wirelessly to a single central transponder mounted on feeder 2. The placement of feeder 1 with a southern facing orientation may have reduced the communication between the pasture 1 transceivers and the central data recording transponder mounted on the western facing portion of feeder 2 and resulted in the increased event maximum gap measurements. A similar situation may have hindered the right and left readings from feeder 3 as they were in closer proximity to the feeder than the center receiver. This design was used for this experiment to simplify data collection from multiple feeders. It is expected that the most common use of the feeder readers would be in a standalone system with onboard data processing and storage. However, if setups are promoted with data sharing from multiple feeders to a common data processing and storage location, orientation and placement of transceivers will need to be considered. If the data from feeder 2 is considered which should have had the least secondary reception/transmission failures, the maximum gap for all 3 transceivers on feeder 2 for the 72 hr period averaged 3 min and 39 sec with at standard deviation of 12 sec. The average maximum gap for the same measure was 2 min and 2 sec with a standard deviation of 5 sec.

In determining which feeder setup produced the lowest reception gaps, all feeders were first compared using least square means (Table 3.3). It was found that feeder one was an outlier. Between feeders two and three, it was found that feeder two, with the on-feeder central transponder, produced the lowest reception gaps ($P<.01$). To determine which receiver placement within the individual feeder produced the lowest reception gaps, feeder two was considered because its setup was most similar to real world conditions, and also because its on-feeder transponder produced the lowest gaps. As seen in table 3.4, it was found that the center receiver produced the lowest event maximum gaps ($P=.1$).

Due to the average maximum gap time of 0:07:14±0:06:47, a safety time of six minutes was chosen for future designs, so that the feeder door will stay open for six minutes after the reception of the last bolus message. This means that to fail, the ultrasonic safety sensors would have to fail to detect any present cattle, and the receiver would have to fail to receive three transmitted bolus messages, because the bolus transmits roughly every two minutes. This setup should provide optimal safety in future designs, which is one of the primary goals of this study.

Attendance data from feeders two and three was compared, because feeder one had already been excluded as an outlier (Table 3.3). Visits per calf per day and feeding time per calf per day were analyzed from the video data, and the results are shown in tables 3.5 and 3.6 respectively. It was found that for visits per calf per day, there was a significant day effect, with d 2 having the highest number of visits ($P<0.01$). A significant feeder effect was not seen ($P=0.24$). A significant feeder by day interaction was also found ($P<0.01$). It was found that there was a significant day effect for feeding time (Table 3.6), with d 2 having the highest feeding time per calf (*P*<0.01). A significant feeder effect was also found, with feeder 3 having the highest feeding time per calf(*P*=0.05). No significant feeder by day interaction was seen (*P*=0.13). These day to day variations in feeding time and visits are most likely due to weather effects. The variation seen in feeding time is most likely attributable to the restricted access at feeder two, causing calves to spend less time feeding at feeder two than at feeder three.

The estimated visits per day per calf, as obtained from the active RFID reception logs, was plotted against the recorded visits per day per calf obtained from the video data. This chart can be seen in figure 3.8. The purpose of this comparison was to hopefully establish a means of electronically monitoring attendance data. The comparison produced an R^2 value of 0.14, which shows a relatively poor correlation. However, this technology still shows promise, and with further research and mathematical analysis, may yet yield a reliable and precise form of electronically monitoring attendance at creep feeders.

IMPLICATIONS

The use of active RFID transmitters in cattle herds has many possibilities, far beyond activating controlled access creep feeders. Active RFID transmitters may eventually be used in mobile reading systems with many applications, for example detecting cattle presence and determining inventory numbers. Other possibilities include metering feed distribution from truck bed and other mobile feeders and controlling access to cattle facilities. The temperature feature on active RFID boluses may also be used for many varied applications, including keeping track of herd health, and heat and calving detection. In the future, new sensor features may also be developed, such as pressure sensors for bloat detection and pH sensors for detecting acidosis. This is an area requiring further research for the realization of the many and varied potential applications.

Table 3.1 Standard creep feed ration containing 15% salt as an intake limiter. All quantities are on an as fed basis.

Item	Concentration
Rolled corn	30.08%
Soybean meal	12.85%
Wheat midds	15.20%
Cottonseed hulls	10.86%
Oats	12.67%
Cane molasses	2.71%
Limestone	1.09%
Salt	14.48%
Vitamin A-30,000	0.02%
Vitamin E-50%	0.02%
Bovatec 91[1]	0.03%

[1]Source: Pfizer Animal Health, New York, NY

Table 3.2 Minimum, maximum and average maximum gaps between receptions for each of the three transceivers on each of the three feeders, as well as the additional directional transceivers on feeder two.

Feeder	Receiver	Minimum Gap[1]	Maximum Gap[2]	Event Maximum Gap[3]	Feeder Avg[4]
1	Right	0:00:39	0:43:53	0:12:52	
1	Center	0:00:00	1:15:37	0:19:36	
1	Left	0:02:07	0:35:56	0:16:27	0:16:18
2	Right	0:01:09	0:03:37	0:02:07	
2	Center	0:00:56	0:03:42	0:01:55	
2	Left	0:01:04	0:03:54	0:02:05	
2	Box	0:01:02	0:03:24	0:02:01	0:02:02
3	Right	0:01:50	0:21:41	0:07:52	
3	Center	0:00:29	0:02:35	0:01:36	
3	Left	0:01:02	0:40:25	0:05:49	0:05:06
	Average	0:01:01	0:16:02	0:07:14	

[1]The lowest recorded amount of time between receptions during a congregation when calves were present at the feeder, shown by receiver. All times are in hrs:minutes:seconds format.

[2]The highest recorded amount of time between receptions during a congregation when calves were present at the feeder, shown by receiver. All times are in hrs:minutes:seconds format.

[3]The average of the highest recorded amount of time between receptions from each congregation when calves were present at the feeder, shown by receiver. All times are in hrs:minutes:seconds format.

[4]The average shown by feeder of event maximum gap times. All times are in hrs:minutes:seconds format.

Table 3.3 Analysis of daily maximum gap and event maximum gap feeder and receiver interactions.

	Feeder 1				*P*-value		
	Left	Center	Right	SEM[1]	Feeder	Receiver	Feeder*receiver
Daily max gap	35.93	52.27	24.41	12.72	0.00	0.54	0.1
Event max gap	16.44	19.22	11.89	4.91	0.00	0.62	0.23
	Feeder 2				*P*-value		
	Left	Center	Right	SEM[1]	Feeder	Receiver	Feeder*receiver
Daily max gap	2.78	2.63	3.22	12.72	0.00	0.54	0.1
Event max gap	2.11	1.90	2.17	4.91	0.00	0.62	0.23
	Feeder 3				*P*-value		
	Left	Center	Right	SEM[1]	Feeder	Receiver	Feeder*receiver
Daily max gap	22.90	2.10	13.12	12.72	0.00	0.54	0.1
Event max gap	10.11	1.70	6.71	4.91	0.00	0.62	0.23

[1]Standard error of the least square means. Largest SEM shown.

Table 3.4 Analysis of the per sensor daily maximum gap and event maximum gap on feeder 2.

		Feeder 2				
	Left	Center	Right	Box	SEM[1]	*P*-value
Daily max gap	2.78	2.63	3.22	2.59	0.46	0.77
Event max gap	2.11[a]	1.9[b]	2.18[a]	2.07[ab]	0.07	0.10

[1]Standard error of the least square means. Largest SEM shown.

Table 3.5 Visits per d as analyzed from the video data. Feeder one excluded because it is an outlier.

	Feeder 2				*P*-value		
	d 1	d 2	d 3	SEM[1]	d	Feeder	Feeder*d
Visits per d	3.63	4.53	1.95	0.46	0.00	0.24	0.01
	Feeder 3				P-value		
	d 1	d 2	d 3	SEM[1]	d	Feeder	Feeder*d
Visits per d	2.74	4.74	3.95	0.46	0.00	0.24	0.01

Table 3.6 Amount of time spent feeding per calf per day as analyzed from the video data. Feeder one excluded because it is an outlier.

	Feeder 2				*P*-value		
	d 1	d 2	d 3	SEM[1]	d	Feeder	Feeder*d
Minutes per d	65.09	90.00	38.33	10.10	0.00	0.05	0.13
	Feeder 3				P-value		
	d 1	d 2	d 3	SEM[1]	d	Feeder	Feeder*d
Minutes per d	58.30	113.49	70.42	10.10	0.00	0.05	0.13

Figure 3.1 Temperature sensing, active RFID rumen bolus sold by Strategic Solutions International, LLC, Stillwater, OK

Figure 3.2 Paint brands applied to calves for video identification.

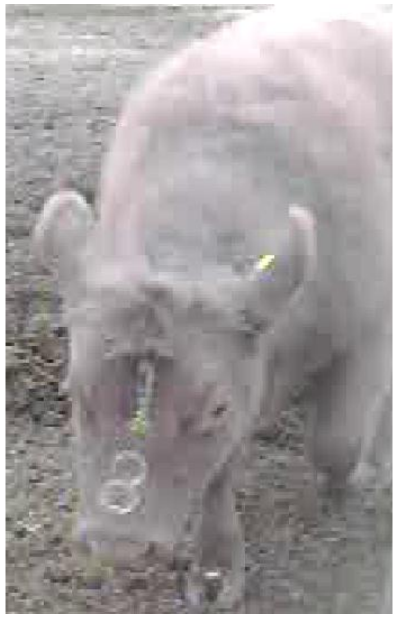


Figure 3.3 Pasture map showing creep feeder placement. White dots mark approximate feeder location.

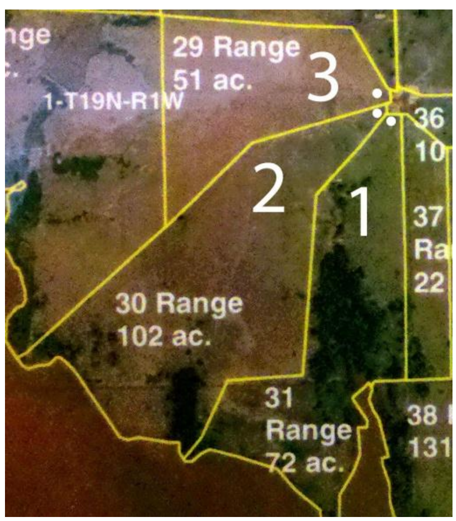


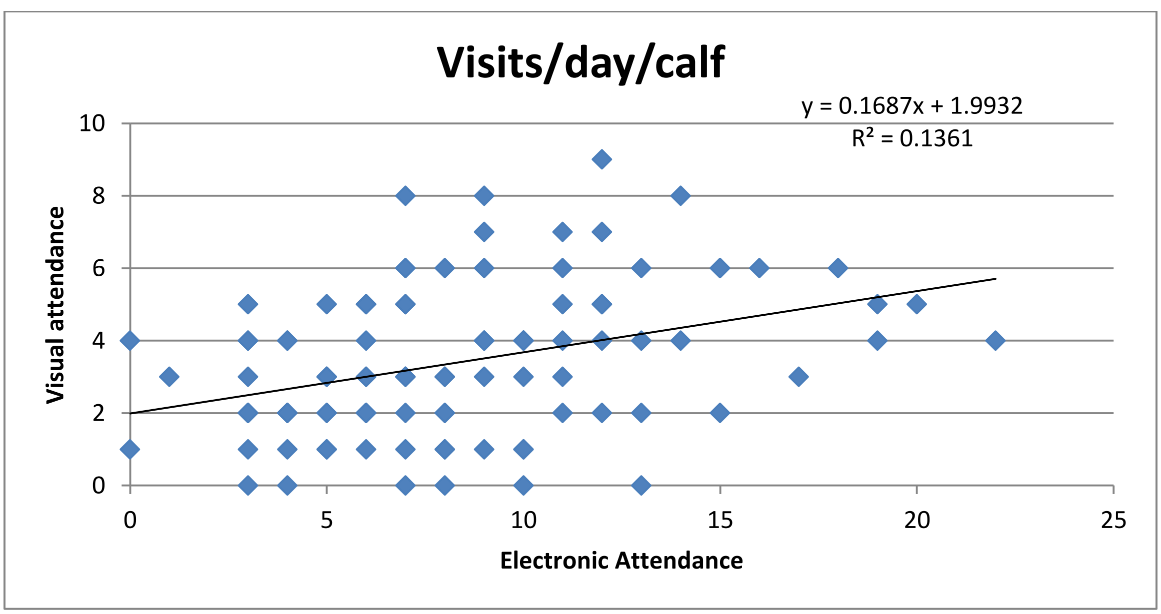
Figure 3.4 Stock creep feeder made by 3C Cattle Feeder Company, Mill Creek, OK

Figure 3.5 Treatment 2, showing 2 of the 3 entranceways blocked, as well as the passive RFID panel reader mounted on the side, and the center active RFID reader (blue box) mounted on the T bar.

Figure 3.6 Camera placement used to record calf entry and exit. Orange circles show the placement and arrows show the point of view of each camera.

Figure 3.7 Active and passive RFID receiver placement on creep feeders one through three. The orange circles represent receiver placement, with one receiver on a post suspended above the center of the feeder, and two receivers on the inside of the feeding area, one on the left and one on the right. The orange box represents the placement of the panel reader on the inside bars of the feeder gate.

Figure 3.8 Graph showing comparison of visually collected visits per day per calf versus electronically estimated visits per day with an R^2 value of 0.14.



CHAPTER IV

EVALUATION OF ELECTRONIC CONTROLLED DOOR SYSTEMS FOR EXCLUSION OF FERAL ANIMALS FROM CATTLE CREEP FEEDERS

ABSTRACT: An experiment was performed to evaluate electronic controlled systems for exclusion of feral animals from cattle creep feeders. Forty-five suckling calves were bolused with active rumen bolus RFID transmitters (Strategic Solutions International, LLC, Stillwater, OK), stratified by weight and randomly assigned to three pastures. Feeder design treatments consisted of a back opening door design, an up opening door design, and a completely open control feeder evaluated in a 3x3 Latin square treatment structure. Calves were adapted to the creep feeders during a 23 d adaptation period during which calves had access to all 3 creep feeder designs, followed by three 21 d periods during which the creep feeders were rotated between pastures. Parameters measured included feed disappearance. The back and up opening feeders were fitted with RFID receivers and data storage devices. This data was used to evaluate calf attendance parameters between the two door designs over each 21 d period. Additionally, 24 hr of video data from every feeder each period was used to compare attendance paramaters between all three feeder designs. A significant feed disappearance effect due to type of feeder was found (P=0.13) with the control feeder having the highest rate of disappearance, and the back and up

treatment feeders having lower and statistically similar amounts of disappearance (*P*=0.94). It was found that the up opening door design was most successful at excluding feral animals, and also the most reliable. It was also found that the completely open control design had the highest rate of feed disappearance.

Keywords: Cattle, active RFID, creep feed, feral swine, raccoon, rumen bolus

INTRODUCTION

Feral animals, particularly feral swine, have become an increasingly prevalent nuisance throughout the United States, especially in the warmer climes of the southern states. In 2006, feral swine were surveyed to have spread to 44 different states (Hutton et al., 2006). In 2000, it was estimated that the feral swine population was at least 4 million individuals, causing an estimated damage of over $800 million annually throughout the United States (Pimentel et al, 2000). Feral swine are also known to be a reservoir for at least 37 different parasites (Forrester, 1991) and thirty different viral and bacterial diseases (Williams et al., 2001). Feral swine and other feral animals have been known to enter creep feeders, spreading feces, mucus and other bodily fluids, creating another potential for contamination and disease spread. For these reasons, creep feeding rangeland calves has largely fallen out of use in certain areas of the United States.

The objective of this study was to evaluate electronic controlled door systems for reduction of feral animal feed consumption. If successful, this would make creep feeding a viable and economical choice in light of new pressures on the cattle industry, including rising costs, growing feral swine populations and widespread drought conditions Much design work and planning was performed prior to the start of the study in order to narrow ideas to the two most successful feral animal exclusion designs for testing, both of which essentially amounted to doors used to cover feed and exclude feral animals, while opening for calves using a sensor trigger. Active RFID transmitters and receivers were chosen based on observations and the results of previous studies. These designs may prove to be able to successfully revive creep feeding as an option for farmers and ranchers in all parts of the United States.

MATERIALS AND METHODS

Cattle

Forty-five suckling calves (average BW=136.1±30.4 kg) were selected in February 2011 from the Oklahoma State University range unit herd. Each calf was weighed on February 4, 2011, and administered a uniquely identified active RFID rumen bolus (Strategic Solutions International LLC, Stillwater, OK) shown in figure 4.1. Calves were stratified by weight and randomly sorted into three treatment groups of 15 each. For the first 23 d of the study, calves intermingled and had access to all three pastures and feeder designs. For each subsequent 21 d period, calves were confined to their treatment group in a randomly assigned pasture. Throughout the study, calves and cows were fed ad libitum prairie grass hay, and calves were fed a creep feed diet ad libitum, containing approximately 15% salt as a feed intake limiter (Table 4.1). Hay feeders were located approximately 200 m from the creep feeders, and water sources were lake shore access located on the far west side of pastures 2 and 3, and a stock pond located on the far western side of pasture 1.

Treatments

Each pasture contained a fixed group of calves, while the three feeders were rotated throughout the pastures in a 3x3 Latin square design (Table 4.2). See figure 4.5 for a map showing the feeder placement within each pasture. Two creep feeders (3C Cattle Feeder Company, Mill Creek, OK) were outfitted with active RFID receivers, and feral animal exclusion door designs, with one feeder featuring an “up opening” design (Figure 4.2), and one feeder featuring a “back opening” design (Figure 4.3). The up opening design consisted of a metal door that moved up and down around a hinge located on the back of the feeding area, and moved upwards to uncover feed when the attached actuator was activated by an active RFID reception. The back opening design moved forward and backward around a hinge located on the inside of the top of the feeding area, and moved backwards to reveal feed when the attached actuator was activated by an active RFID reception. Only one side of each feeder was used for this experiment, with the other being placed against a fence making it inaccessible to calves. The active RFID receiver placement was the same for each feeder, with one receiver mounted on the lip of the feeder in order to receive signals while animals were inside the feeder, while the other receiver was mounted on a pole above the feeder in order to receive signals from approaching animals and open the feed door prior to animal entry. A third feeder was left completely open, with no door design and no RFID receivers (Figure 4.4). All feeders were powered using wall outlet power during this experiment.

Data Collection

At the beginning of every 21 d period, feed entering the feeder was weighed, and at the end of each period, feed was weighed back in order to provide a measure of feed disappearance. Feeders were kept continuously stocked with all feed added weighed and recorded in order to assure calves were fed ad libitum. Also, all active RFID bolus data was recorded throughout each 3 wk period, in order to determine electronically measured attendance calculations. Each data point consists of the time the message was received, as well as the unique ID number of the bolus from which it was received, and the ruminal temperature of the calf. This data was collected by two active RFID receivers positioned on each feeder, and stored on a thumb drive contained within the control unit of the feeder. Also during each period, 24 hrs of video surveillance data was collected in one session, which was used to determine visual attendance calculations, as well as the amount of time feral animals spent at each feeder.

Data Analysis

Video data was analyzed from all three treatments to determine a number of attendance calculations, including average length of each individual visit to the feeder, average total minutes spent at the feeder per calf per d, and also average minutes per head of feral animal feeding time. These calculations were juxtaposed with calculations obtained from the active RFID logs on the two treatment feeders, which included a calculated average total minutes spent at the feeder per calf per d, obtained by multiplying the average number of messages received per head per d by the transmission rate of two minutes per message. The average percentage of d messages were received from each bolus was also calculated using the active RFID log data. Feed disappearance data was analyzed using a least square means analysis in proc mixed of SAS 9.2 (SAS Institute Incorporated, Cary, NC).

RESULTS AND DISCUSSION

When feed disappearance data was analyzed, it was found that the control feeder was statistically different from the up opening and back opening treatments (P=0.03), which were not statistically different from each other ($P \geq 0.21$). It was found that the control feeder had the highest feed disappearance across all three periods, with an average of 302.7±110.0 kg, as compared to the treatment feeders which had an average disappearance of 85.7±40.9 kg. Average disappearances per calf per d were 1.0±0.34 kg for the control feeder and 0.3±0.13 kg for the treatment feeders. All disappearances are reported on an as-fed basis. See table 4.3 for a table of disappearances by period, and table 4.4 for statistical analyses of the feed data. When compared with the video based feral animal attendance data found in table 4.6, the reason for the significantly higher feed disappearance on the control feeder seems to be at least partly due to increased feral animal feeding time, considering that feral animals spent an average of almost three hrs per d feeding on the open feeder, as opposed to only one hour and forty one minutes on the back opening feeder, and no time at all on the up opening feeder. Not only does this include feral animal feeding, but also waste due to feral animal sorting of feed. The back opening feeder showed some feral animal feeding time during the second phase of the experiment due to a design flaw that allowed raccoons to enter the feeder over top of the door design. This was corrected with an additional metal guard after the second 21 d period, which may account for some of the drop in feed disappearance seen in the third phase as feral animals were no longer feeding on this treatment. This shows that feed disappearance rates in this creep feed trial, and possibly many creep feed trials in the past, cannot be directly correlated with cattle intake due to the confounding factor of feral animal feed consumption.

Various cattle attendance calculations were taken from both the visual data and the electronically recorded bolus logs. Electronic bolus log calculations were compared with visual logs on treatment feeders only. This data can be seen in table 4.5. This data does further demonstrate that this current technology may be useful for estimating feeding time per head based on bolus messages received. Between the treatment and control feeders, visually gathered calculations taken from the video data were compared. This data can be seen in table 4.6. It is important to note that cattle visited the control feeder more frequently, as can be seen from their higher overall feeding time, but similar feeding time per visit. It is possible that on the treatment feeders the door design may be visually negative to the cattle, although no empirical evidence of this was seen. This increased attendance may indicate increased calf feeding, and may be another factor contributing to increased feed disappearance numbers on the control feeder.

Apart from being less efficient, the back opening door design did not adequately exclude feral animals without several costly and difficult design additions, and also did not provide the additional benefit of protecting feed from rain water. Furthermore, the back opening door design had the propensity to clog on feed, disabling the motor and making it a less than ideal choice. The outfitting of the back opening door also prevented easy access to the feed flow rate adjustment. Due to the outstanding lack of feral animal feed consumption, as well as ease of production and outfitting, and the fact that feed is protected from water, the “up opening” door design was chosen as the most appropriate for production use. This technology is still in prototype and testing stages, so production costs are not known, although it is estimated that that the technology will not be more than $1200 in addition to the cost of the creep feeder itself.

IMPLICATIONS

Implementation of this technology has the potential to redefine creep feeding. Use of these designs could make it possible to creep feed cattle in areas of the country where creep feeding has fallen out of use due to feral animal feed consumption. This could have significant economic impact, especially in drought stricken areas, where calves may be retained on creep feed where they would otherwise have been sold. This also has significant ramifications for science, where creep feeders may now possibly be studied without the influence of feral animals. Coupled with the use of active RFID transmitters, these designs could also be used to study the effect of different diets on individuals or groups of cattle, furthering the scientific process. Finally, active RFID outfitted creep feeders such as these may in the future be used as a sort of hub for information about pastured cattle, recording important information such as attendance and rumen temperature of not only calves but whole herds, and using this data for many uses such as herd inventory, disease detection, heat detection and automated feeding.

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Table 4.1 Standard creep feed ration containing 15% salt as an intake limiter. All percentages reported on an as-fed basis.

Item	Concentration
Rolled Corn	30.08%
Soybean Meal	12.85%
Midds	15.20%
Cottonseed Hulls	10.86%
Oats	12.67%
Cane Molasses	2.71%
Calcium	1.09%
Salt	14.48%
Vitamin A-30,000	0.02%
Vitamin E-50%	0.02%
Bovatec 91	0.03%

Table 4.2 Latin square rotation used to account for cattle variability.

		Period		
		1	2	3
	1	Back	Control	Up
Field	2	Control	Up	Back
	3	Up	Back	Control

Table 4.3 Feed intake by feeder and period reported on an as-fed basis.

Control Feeder Mean= 302.7±110.0

Phase	Feed disappearance (kg)	Kg/calf/d
1	181.8	0.6
2	396.9	1.3
3	329.4	1.0

Up feeder Mean= 82.8±52.3 kg

Phase	Feed disappearance (kg)	Kg/calf/d
1	142.7	0.5
2	59.9	0.2
3	45.9	0.1

Back feeder Mean= 88.7±37.8 kg

Phase	Feed disappearance (kg)	Kg/calf/d
1	129.0	0.4
2	83.0	0.3
3	54.0	0.2

Table 4.4 Analysis of feed disappearance data.

	Feeder				
	Back	Control	Up	SEM[1]	*P*-value
Feed disappearance	88.7^{a}	302.7^{b}	82.8^{a}	48.8	0.13

[1]Standard error of the least square means.

Means without a common superscript differ (*P*<0.1)

Table 4.5 Selected visual and electronic attendance data from treatment feeders only. Main comparison of note is average head minutes/head/d as compared with electronically calculated feeding minutes per day. All times are indicated in h:mm:ss format.

Visual Data		Electronic Data	
Avg head min/visit	0:05:00	Avg msgs/hd/d	9.3
Avg total head min/d	0:02:37	Percent d read	59%
Avg head min/hd/d	0:10:00	# msgs x 2 min transmission interval = min/d	0:19:00

Table 4.6 Comparison of 24 h attendance data collected from video on all feeders. All times are in h:mm:ss format.

Back		Up		Open	
Avg total head min/d	0:02:46	Avg total head min/d	0:02:34	Avg total head min/d	0:05:12
Avg head min/visit	0:04:00	Avg head min/visit	0:03:00	Avg head min/visit	0:04:00
Avg head min/hd/d	0:11:00	Avg head min/hd/d	0:10:00	Avg head min/hd/d	0:20:00
Avg feral head min/d	1:41:00	Avg feral head min/d	0:00:00	Avg feral head min/d	2:57:00

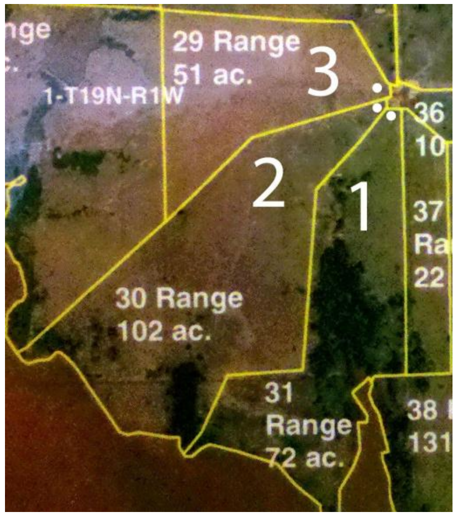
Figure 4.1 Temperature sensing, active RFID rumen bolus produced by Strategic Solutions International, LLC, Stillwater, OK .

Figure 4.2 Up opening door design on treatment feeder. RFID receiver placement on pole and feeder lip can also be seen (circled in orange).

Figure 4.3 Back opening door design on treatment feeder.

Figure 4.4 Standard 3C Cattle Feeder Co. feeder with completely open design.

Figure 4.5 Pasture map showing creep feeder placement. White dots mark approximate feeder location.



APPPENDIX

All procedures involving live animals were approved by the
Oklahoma State University Institutional Animal Care and Use Committee.

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VITA

Joe Simmons

Candidate for the Degree of

Master of Science

Thesis: DEVELOPMENT OF TECHNOLOGY TO EXCLUDE FERAL ANIMAL FEED CONSUMPTION FROM CALF CREEP FEEDERS

Major Field: Animal Science

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Completed the requirements for the Master of Science in Animal Science at Oklahoma State University, Stillwater, Oklahoma in December, 2011.

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Farmhand, University of Delaware Newark Farm: Oct. 2006-Dec 2008
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Name: Joe Simmons Date of Degree: December, 2011

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: DEVELOPMENT OF TECHNOLOGY TO EXCLUDE FERAL ANIMAL FEED CONSUMPTION FROM CALF CREEP FEEDERS

Pages in Study: 44 Candidate for the Degree of Master of Science

Major Field: Animal Science

A series of experiments was performed with the objective of creating a system to exclude feral animals from calf creep feeders. The first experiment evaluated three different electronic sensor systems for accuracy of identifying calves attending a mobile creep feeder. Efficacy of sensor placement for active RFID rumen technologies was evaluated. Fifty seven post-weaning calves were stratified by weight and randomly assigned by to three pastures, each containing a single creep feeder outfitted with one of several combinations of electronic sensor technologies. All calves were also administered an active RFID rumen bolus. Creep feeders 1 and 3 were equipped with three active RFID readers, one on the left side of the feeder, one on the right, and one suspended on a post on the center of the feeder. Creep feeder 2 was equipped with the same configuration of active RFID readers, as well as one directional RFID reader, and one large size passive RFID panel reader. Each feeder was also equipped with ultrasonic sensor systems, although due to equipment failures these systems did not produce any results. Active RFID data was collected for 25 d, passive RFID data was collected for 4 d, and video cameras recorded the same 4 d, for evaluation of accuracy of active and passive data. This data was analyzed to find accuracy of passive RFID sensor technology, maximum gap in receptions for each active RFID sensor configuration, and also to determine any general improvements to each system. It was determined that the passive RFID system was able to detect 87% of calf entries into the feeder. It was also found that the average of the highest amount of time between active RFID message receptions between all receivers was 0:07:14±0:06:47 (h:mm:ss) during a congregation where calves were physically present at the feeder. Data from this study suggests that active RFID bolus transmitters may be suitable for identification of calf attendance at creep feeding sites. The second experiment evaluated electronic controlled systems for exclusion of feral animals from cattle creep feeders. Forty-five suckling calves were bolused with active rumen bolus RFID transmitters, stratified by weight and randomly assigned to three pastures. Feeder design treatments consisted of a back opening door design, an up opening door design, and a completely open control feeder evaluated in a 3x3 Latin square treatment structure. Calves were adapted to the creep feeders during a 23 d adaptation period during which calves had access to all 3 creep feeder designs, followed by three 21 d periods during which the creep feeders were rotated between pastures. Parameters measured included feed disappearance. The back and up opening feeders were fitted with RFID receivers and data storage devices. This data was used to evaluate calf attendance parameters between the two door designs over each 21 d period. Additionally, 24 hr of video data from every feeder each period was used to compare attendance paramaters between all three feeder designs. A significant feed disappearance effect due to type of feeder was found (P=0.13) with the control feeder having the highest rate of disappearance, and the back and up treatment feeders having lower and statistically similar amounts of disappearance (P=0.94). It was found that the up opening door design was most successful at excluding feral animals, and also the most reliable. It was also found that the completely open control design had the highest rate of feed disappearance.

ADVISER'S APPROVAL: Dr. Chris Richards